ADOLESCENT PERSONALITY MODERATES THE TESTOSTERONE-EXTERNALIZING ASSOCIATION

A Thesis Presented to

The Faculty of the Department of Psychology

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Kathleen W. Reardon

May 2014

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ABSTRACT

In considering moderating factors of the complex association between testosterone, a steroid hormone, and externalizing behavior, previous research has mainly focused on environmental influences, including interpersonal relationships. I tested the hypothesis that self-regulatory personality, an individual-level variable that is relevant for other hormone-behavior associations, moderates the testosterone-externalizing behavior association in adolescence. I examined evidence for this moderation across age and subfactors of externalizing behavior (aggression and rule-breaking). Parents reported on their child's personality and psychopathology for a sample of 106 adolescents (56 % female) aged 13-18 (M = 16.01 years, SD = 1.29 years). Adolescent testosterone levels were measured via passive drool samples. As hypothesized, both trait Agreeableness and Conscientiousness moderated the testosterone-externalizing problem relationships. Specifically, high testosterone predicted higher levels of Externalizing Behaviors, but only for adolescents low in Agreeableness and Conscientiousness. In addition, self-regulatory personality acted as both a risk and a resiliency factor, with high levels of Conscientiousness—in combination with high testosterone—predicting lower than average levels of rule-breaking. These findings are similar to previously reported results regarding interpersonal relationships, which raises the question of how environmental and endogenous factors might jointly interact with high testosterone. Additionally, this work highlights the relevance of including personality moderators in future research on hormone-behavior associations.

CONTENTS

The joint study of biological and behavioral variables can offer unique insight into the underlying mechanisms driving the development of psychopathology. The relationship between the steroid hormone testosterone and various forms of externalizing behavior (especially aggression; Archer, 2006) has been an important area of empirical focus. Testosterone has been highlighted as a potentially important risk factor for externalizing psychopathology, which suggests that it may be a useful variable to include when focusing research attention on the etiology of these behaviors (Maras et al., 2003). Especially in adolescence, however, the connection between testosterone and externalizing behavior appears to be complex, and results thus far have been mixed (Ramirez, 2003).

Testosterone is a gonadal hormone primarily responsible for the development and maintenance of male secondary sex characteristics (Forbes & Dahl, 2010; Sisk & Zehr, 2005). Although it is present in males and females, overall levels are typically higher in males (Nelson, 2000). In animal research, the link between testosterone and displays of aggression is well established (Archer, 1988), providing the impetus for extending this link to human populations.

In both youth and adults, higher levels of testosterone have been linked to aggression, social dominance, and conduct problems (Archer, 2006; Cashdan, 1995; Josephs, Newman, Brown & Beer, 2003; van Bokhoven et al., 2006). Specifically, research has found testosterone administration to increase aggression in men (Pope, Kouri & Hudson, 2000), and numerous studies have found increased aggression among

those with high testosterone in adult male inmate populations (Dabbs, Carr, Frady & Riad, 1995; Ehrenkranz, Bliss & Sheard, 1974) and male military veterans (Dabbs & Morris, 1990). There have also been numerous studies, however, that find no connection between aggression and testosterone (Aluja & Garcia, 2007; Archer, Graham-Kevan & Davies, 2005; Glenn, Raine, Schug, Gao, & Granger, 2011; Granger et al., 2003; van Goozen, Matthys, Cohen-Kettenis, Thijssen, & van Engeland, 1998), and some evidence for a negative association between these constructs (Book, Starzyk, & Quinsey, 2001). Meta-analyses support a weak, positive correlation between aggression and testosterone (Archer, 1991; Book et al., 2001; Ramirez, 2003; Rubionw & Schmidt, 1996), with minimal understanding regarding the differences that have emerged across studies.

Although previous researchers have sought to explain the seemingly contradictory findings regarding a testosterone-externalizing association, personality characteristics have not yet been considered as a moderator of the testosterone-externalizing association. Personality characteristics represent one domain with great potential for elucidating other hormone-behavior associations (Gunnar, Kryzer, Van Ryzin, & Phillips, 2011; Phillips, Fox, & Gunnar, 2011; Shoal, Giancola, & Kirillova, 2003; Tackett, Kushner, Josephs et al., 2014), which implies they may be meaningful in the context of the testosterone-externalizing behavior association as well. Personality traits are broadly defined and normally distributed in the population, offering a useful background for teasing apart individual differences in associations with biological markers (De Young et al., 2010). Specifically, self-regulatory personality traits (i.e., agreeableness and conscientiousness) show robust associations with externalizing behavior (Nigg, 2006; Tackett, 2006).

Overall, conscientiousness and agreeableness have been negatively correlated with externalizing behavior (John, Caspi, Robins, Moffitt, & Stouthamer-Loeber, 1994; Miller, Lynam, & Jones, 2008), and low conscientiousness and agreeableness predict aggression and conduct-disordered behavior (Settles et al., 2012). John and colleagues (1994) also found that there were mean-level differences for boys high in externalizing behavior in the negative association with both conscientiousness and agreeableness compared to those adolescents who were not categorized as externalizers. Thus, the inclusion of self-regulatory personality traits may help disentangle associations between testosterone and externalizing problems.

Potential Influences on Adolescent Testosterone-Externalizing Associations

Although personality traits have not been specifically investigated in this domain, researchers have previously examined other moderators of the testosterone-externalizing behavior relationship including gender, age, stress, circadian rhythm, offender status, and method of testosterone measurement (Book et al., 2001; Rubinow & Schmidt, 1996). One domain that has found to be important is interpersonal relationships. For example, Rowe and colleagues (2004) demonstrated that the association between high testosterone and conduct disorder symptoms in adolescent boys was specific only to those boys with deviant peer group affiliations. In an extension of this work, Vermeersch and colleagues (2008) found a significant relationship positive relationship between testosterone and non-aggressive risk-taking. Specifically, they found that boys with high levels of testosterone hade friend who were involved in more risk-taking, and that the influence of those friends contributed to higher risk-taking outcomes. Ryan and colleagues (2013)

found that those boys who had both high testosterone and high levels of deviant peer affiliation showed less improvement in externalizing behaviors during treatment. Extending these findings to other relational domains, one study demonstrated that children with high testosterone showed greater risk-taking behavior when parent-child relationship quality was poor (Booth, Johnson, Granger, Crouter & McHale, 2003). Taken together, these findings suggest that high testosterone is primarily associated with antisocial behavior in the context of high-risk relationships.

It is equally important to note that Rowe and colleagues (2004) also demonstrated a resiliency effect, such that for those boys with no evidence of deviant peer group associations, high testosterone was associated with leadership. Additionally, in the study conducted by Booth and colleagues (2003), those boys with high testosterone and positive relationships with their mothers demonstrated lower levels of risk behavior, another example of a resiliency effect. One provocative hypothesis that arises from these resiliency findings is whether intrapersonal characteristics, such as self-regulatory personality traits, might show similar moderating effects in the context of the testosterone-externalizing behavior relationship. This was the focus of the present investigation.

In addition to testing this primary hypothesis, I wanted to examine two other potential moderators of the testosterone-externalizing association: behavioral subtypes of externalizing behavior and age. Although aggression has been the focus of the majority of research investigating the association between testosterone and externalizing behavior, there has been some work examining other externalizing outcome variables as well.

Attributes that are conceptually related to aggression have been examined in connection with testosterone levels; these include social dominance (control over others exerted through aggression), timidity (lack of aggression) and provocation (acts likely to be met with aggression), but much like in the testosterone-aggression literature, findings are not definitive for these outcomes either (Archer, 1991). Additionally, testosterone has been linked to non-aggressive risk taking in adolescent boys (Vermeersch, T'sjoen, Kaufman & Vincke, 2008), elevated externalizing behavior scores on the Child Behavior Checklist in at-risk adolescent boys (but not in girls; Maras et al., 2003), and deviant behavior (specifically property or financial offenses and assaults or fighting) in adults (Booth & Osgood, 1993).

One classification of youth externalizing behavior often distinguishes between delinquent or rule-breaking behavior and aggressive behavior (Achenbach & Edelbrock, 1978; Burt, 2012; Stanger, Achenbach, & Verhulst, 1997; Tackett, Krueger, Sawyer, & Graetz, 2003). Rule-breaking behavior reflects behavior such as running away from home, being truant, and vandalizing (Achenbach & Edelbrock, 1978), whereas aggression reflects behaviors such as fighting, bullying, and being cruel to others (Frick et al., 1993). These two subfactors have been differentiated in terms of developmental course (Moffitt, 1993). Previous research has also suggested that the distinction between aggression and rule-breaking may be useful for identifying unique biological causes (Lahey, Waldman, & McBurnett, 1999). Indeed, etiologic influences are different across the two subfactors (Tackett, Krueger, Iacono & McGue, 2005). Specifically, aggression is found to have a higher genetic contribution (Tackett et al., 2005), which implies that it could relate more

strongly to biological variables such as testosterone. However, testosterone is susceptible to environmental influences, as well (Carré & McCormick, 2008; Maner, Miller, Schmidt & Eckel, 2008), which are more strongly implicated in rule-breaking behaviors. Additionally, Vermeersch and colleagues (2008) examined the impact of testosterone on both aggressive and non-aggressive risk-taking behaviors, and found significant effects only for non-aggressive risk-taking. These results suggest that the distinction between aggressive and delinquent behaviors may be important in the context of their relationship to testosterone. It is difficult to formulate specific hypotheses in this particular domain, but I am interested in whether behavioral heterogeneity within the externalizing domain may partially account for previous mixed or restricted findings.

Another factor that may help to explain heterogeneity in the pathways from high testosterone to various behavioral outcomes is developmental change. There is a vast amount of hormonal, social and maturational change taking place between the ages of 13 and 18 (Cameron, 2004). Most early research on the association between testosterone and externalizing behavior has focused on adult populations, and findings are not consistent across adults and children (Tremblay et al., 1998). The prevalence of overall externalizing disorders peaks in late adolescence (Moffitt, 1993; Moffitt, Caspi, Rutter, & Silva, 2001; Steinberg, 2008; Steinberg & Morris, 2001), and testosterone levels increase dramatically across adolescence (10-fold in males and 2 or 3-fold in females; Booth, Granger, Mazur, & Kivlighan, 2006). The relationship between testosterone and aggression appears variable across stages of development, as well (Ramirez, 2003). Too little evidence exists to formulate specific hypotheses, but I wanted to examine whether

about the nature of the relationship between testosterone and externalizing behavior (in the context of self-regulatory personality) differs across the age range of the current study.

The Present Study

The current study is the first to examine self-regulatory personality traits as moderators of the testosterone-externalizing behavior association in a mixed-gender, adolescent sample.

Specific study aims were:

1. To investigate whether self-regulatory personality traits (agreeableness and conscientiousness) wold moderate the association between testosterone and externalzing problems in adolescence.
    a. I hypothesized that, consistent with mixed findings in the literature, I would not observe a main effect of testosterone on externalizing problems.
    b. I hypothesized that higher levels of testosterone would be associated with higher levels of externalizing behavior, but only for youth low in trait agreeableness and conscientiousness (i.e., only in the context of self-regulatory deficits—evidence for a risk effect).
    c. Additionally, I hypothesized that higher levels of testosterone would be associated with lower levels of externalizing behavior, but only for youth high in trait agreeableness and conscientiousness (i.e., only in

the context of self-regulatory strengths—evidence for a resiliency effect.)

2. To examine differential associations for subfactors of externalizing behavior: rule-breaking and aggression.
3. To examine differential associations across age.

Method

Participants

Participants were 106 adolescents (56% female) between the ages of 13 and 18 years (M = 16.01, SD = 1.29). Data were also collected from the adolescents' caregivers, comprised of 96 mothers and 10 fathers. Informed assent/consent was provided by adolescents and parents at the beginning of the assessment. When reporting on their adolescent's race/ethnicity, 74.5% of parents identified their child as White, 6.6% as Asian Canadian, 4.7% as African Canadian, 0.9% as Latino/Latina, 0.9% as Pacific Islander, and 12.3% as Other/Multiracial. The average annual household income bracket reported by parents was between 70,001–80,000 Canadian dollars. Most parents (87.7%) reported a 4-year college degree or higher, 6.6% reported some college, and 5.7% reported graduation from high school as their highest level of education. Adolescents were recruited as part of a follow-up assessment of a larger study on child personality and psychopathology at the University of Toronto (see Tackett, Kushner, De Fruyt, & Mervielde, 2013). The response rate for participation in the follow-up assessment of the larger study was 80% overall, with 72% participating in the lab and providing hormone samples (the remaining participants completed questionnaires by mail). The inclusion

criterion for adolescents and parents was English fluency. Exclusion criteria were a history of mental retardation, autism, or schizophrenia in the adolescent. Youth participants were compensated with a 25-dollar gift card and their parents received 50 Canadian dollars for participating in the full lab visit and completing questionnaires at home. The university Research Ethics Board approved all study methods and materials.

Measures

Externalizing behavior. Parents completed the Child Behavior Checklist for ages 6-18 (CBCL; Achenbach & Rescorla, 2001) about their adolescent's behavior. The CBCL/6-18 consists of 118 items that describe common problem behaviors. Respondents rated each item on a three-point scale ranging from 0 (*Not true (as far as you know))* to 2 (*Very true or often true)* for the past six months. The Exteranlizing Behavior dimension (35 items) was the focus of the present study and showed good internal consistency in the present sample (Crohnbach's α=.90). The Aggression (18 items) and Rule-Breaking (17 items) subscales each showed good internal consistency as well (Crohnbach's α=.88 and .80, respectively). In addition, the Internalizing Behavior dimension (31 items) was used as a covariate in some analyses, and it also shows good internal consistency in this sample (Crohnbach's α=.86).

Personality. Parents completed the Big Five Inventory (BFI; John, Donahue & Kentle, 1991) about their child. The BFI is a 44-item questionnaire designed to measure the Big Five personality traits. In this study, I focused on the subscales measuring Agreeableness (A; 9 items) and Conscientiousness (C; 9 items). Respondents rated each item on a five-point scale ranging from 1 (*Disagree Strongly)* to 5 (*Agree Strongly)*.

These two traits showed adequate interanal consistency in the present sample (A: Crohnbach's α=.79 and C: Crohnbach's α=.85).

Testosterone. Saliva was collected using the passive-drool method. Participants were asked to drool through a sanitary straw into a 2-ml IBL vial. Testosterone levels were measured from a baseline saliva sample collected approximately 30 minutes after the participants arrived in the lab.

Procedure

As noted, the present investigation focused on a subsample of a larger longitudinal study on child personality and psychopathology (Tackett, Kushner, De Fruyt et al., 2013). From the original assessment, 187 adolescents were invited to participate in a follow-up assessment 1-3 years later. Of those invited, 144 adolescents completed the assessment – 106 of whom completed the assessment in the lab, where saliva samples were collected. These 106 adolescents comprise the sample used in this study. Among other questionnaires, the BFI was mailed to parents for completion and was returned during their lab visit. The CBCL was completed by parents during the lab visit. All female participants were scheduled during the first ten days of their menstrual cycle when hormone levels are most stable (Liening, Stanton, Saini & Schultheiss, 2010). All saliva samples were collected between noon and sundown to account for the diurnal variation of testosterone levels (Kirschbaum & Hellhammer, 1994). Participants were instructed not to eat or drink for two hours and not to smoke for four hours before their assessment. Upon arrival to the lab and once they had provided assent, participants rinsed their mouths with water and drank a small cup of water. After 30 minutes of sedentary activity

(questionnaire completion), participants drooled through a sanitary straw into a 2-ml IBL vial. Samples were frozen at -20ºC before being shipped on dry ice to Clemens Kirschbaum's laboratory at the Technical University of Dresden. Once there, samples were centrifuged at 3,000 rpm for 5 minutes, and immunoassayed (IBL International, Hamburg, Germany). The intra- and interassay coefficients for testosterone were below 8%.

Results

Descriptive statistics and correlations for personality, psychopathology, testosterone, and age variables are presented in Table 1. When examining variable frequencies, no extreme values (defined as more than three standard deviations above or below the mean) were detected. As is common for hormone variables, the distribution of testosterone values showed significant skewness (2.25), which was improved after log-transformation (-.33).

Table 1
Correlation Coefficients and Descriptive Statistics

		1	2	3	4	5	6	7	8
1.	Age	1.00							
2.	Testosterone	.15	1.00						
3.	BFI Agreeableness	-.03	-.14	1.00					
4.	BFI Conscientiousness	.09	-.19*	.41***	1.00				
5.	CBCL Externalizing Behavior	.01	.18	-.18	-.24*	1.00			
6.	CBCL Internalizing Behavior	-.07	.00	.08	-.09	.54***	1.00		
7.	CBCL Rule-Breaking Behavior	.08	-.21*	-.23*	-.24*	.87***	.26**	1.00	
8.	CBCL Aggressive Behavior	-.05	.14	-.11	-.20*	.93***	.66***	.63***	1.00
M		16.01	1.01	3.89	3.39	6.58	6.73	2.43	4.15
SD		1.29	0.54	0.58	0.69	7.24	6.25	3.38	4.61

Note. Values displayed for Testosterone are for the log-transformed variable. BFI = Big Five Inventory. CBCL = Child Behavior Checklist. *$p < .05$. **$p < .01$. ***$p < .001$.

Broadband Externalizing Behavior. Moderation effects for Agreeableness and Conscientiousness were tested via hierarchical regression models. Prior to these analyses, I standardized all independent variables. In the examination of associations with overall Externalizing Behaviors (DV), I first entered the covariates of youth age, gender, and time of waking (Step 1), followed by main effects for testosterone and either Agreeableness or Conscientiousness (Step 2). Next, I entered the corresponding interaction term (testosterone × BFI trait) to investigate the presence of a significant moderation effect (Step 3). Next, I conducted these analyses in the same way, this time with CBCL Internalizing Behavior included as a covariate in Step 1. This was done to examine the specificity of the interaction effect between testosterone and either Agreeableness or Conscientiousness in predicting Externalizing Behavior scores (above and beyond general psychopathology). The results of these analyses are displayed in Table 2. Simple slope analyses were conducted according to Hayes' (2013) PROCESS modeling to probe the interactions which were found to be significant at personality trait levels one *SD* above and below the mean.

When not including Internalizing Behavior as a covariate in the analyses, Agreeableness significantly moderated the testosterone-externalizing relationship (β = -.22, $t(99)$ = -2.25, p = .027), but Conscientiousness did not. Simple slope analyses indicated that testosterone did not significantly predict Externalizing Behavior scores at Agreeableness levels one *SD* above (b = -1.68, $t(99)$ = -1.34, p = .184) or below (b = 1.66, $t(99)$ = 1.53, p = .128) the mean. When including Internalizing Behavior as a covariate in the analyses, the pattern of results for Agreeableness remained the same (β =

-.22 , $t(98) = -2.77$, $p = .007$), and Conscientiousness emerged as a significant moderator of the testosterone-externalizing relationship, as well ($\beta = -.25$, $t(98) = -3.13$, $p = .002$). Simple slope analyses indicated that testosterone positively predicted Externalizing Behavior scores at low ($b = 1.81$, $t(98) = 2.05$, $p = .043$) but not at high ($b = -1.55$, $t(98) = -1.51$, $p = .135$) levels of Agreeableness. Similarly, testosterone positively predicted Externalizing Behavior scores at low ($b = 2.07$, $t(98) = 2.21$, $p = .029$) but not at high ($b = -1.62$, $t(98) = -1.74$, $p = .086$) levels of Conscientiousness. Both of these findings indicate a risk effect for testosterone (see Figure 1).

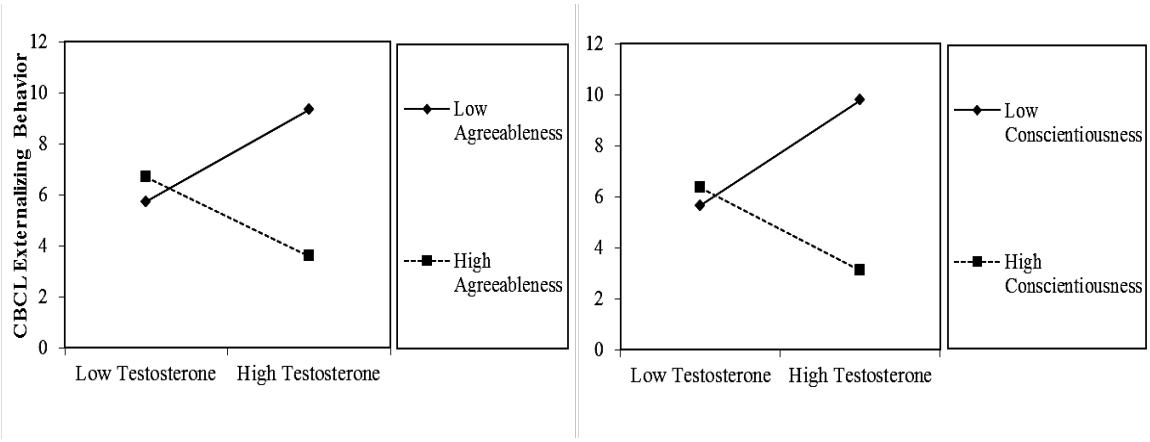

Figure 1. Interactions between testosterone and BFI Agreeableness (left panel) and BFI Conscientiousness (right panel) in predicting CBCL Externalizing Behavior, controlling for CBCL Internalizing Behavior. BFI = Big Five Inventory; CBCL = Child Behavior Checklist.

Rule-breaking behavior versus aggressive behavior. Next, I estimated models predicting Rule-Breaking Behavior scores (controlling for Aggressive Behavior) and Aggressive Behavior scores (controlling for Rule-Breaking Behavior) to address

Note. Separate regression analyses were conducted for each BFI trait to examine the interaction terms between testosterone levels and adolescent personality traits. For both models, gender, age, and time of waking were entered in Step 1 as covariates. Model estimates are displayed for the new variables added at each step. BFI = Big Five Inventory. CBCL = Child Behavior Checklist. Ext Behavior = Externalizing Behavior scale on the CBCL. Int Behavior = Internalizing Behavior scale on the CBCL. R^2 coefficients represent the proportion of variance explained by the predictor variables in that step. *F* denotes significance of the regression model at each step. *B* = unstandardized regression coefficient. *SE* = standard error. Values in brackets are 95% confidence intervals for the regression coefficients.

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 2

Moderated Hierarchical Regression Analyses Predicting Child Behavior Checklist Externalizing Behavior, Rule-Breaking, and Aggressive Behavior scores from Testosterone (Test) and Big Five Inventory (BFI) Self-Regulatory Personality Traits

		DV: Ext. Behavior					DV: Ext. Behavior (covariate: Int. Behavior)				
Step	Variable	*B*	SE_B	95% CI	R^2	*F*	*B*	SE_B	95% CI	R^2	*F*
					Model 1: BFI Agreeableness (BFIA)						
2	TEST	0.30	0.91	[-1.51, 2.11]	.08	1.76	0.44	0.76	[-1.06, 1.94]	.38	10.03***
	BFIA	-0.76	0.74	[-2.23, 0.71]			-1.19	0.62	[-2.41, 0.03]		
3	TEST x	-1.67*	0.74	[-3.14, -0.19]	.13	2.37*	-1.68**	0.61	[-2.88, -.47]	.42	10.27***
					Model 2: BFI Conscientiousness (BFIC)						
2	TEST	0.12	0.90	[-1.66, 1.91]	.10	2.26	0.23	0.76	[-1.27, 1.72]	.37	9.79***
	BFIC	-1.32	0.72	[-2.74, 0.11]			-1.02	0.60	[-2.21 0.18]		
3	TEST x BFIC	-1.30	0.72	[-2.72, 0.13]	.13	2.46*	-1.85**	0.59	[-3.02, -0.67]	.43	10.53***
		DV: RB Beh. (covariate: Agg. Beh.)					DV: Agg. Beh. (covariate: RB Beh.)				
Step	Variable	*B*	SE_B	95% CI	R^2	*F*	*B*	SE_B	95% CI	R^2	*F*
					Model 1: BFI Agreeableness (BFIA)						
2	TEST	-0.04	0.33	[-0.68, 0.61]	.47	14.77***	0.18	0.46	[-0.74, 1.09]	.42	12.16***
	BFIA	-0.35	0.26	[-0.88, 0.17]			0.14	0.38	[-0.61, 0.90]		
3	TEST x	-0.26	0.28	[-0.81, 0.29]	.48	12.78***	-0.39	0.39	[-1.16, 0.39]	.43	10.56***
					Model 2: BFI Conscientiousness (BFIC)						
2	TEST	-0.10	0.33	[-0.74, 0.55]	.47	14.59***	0.18	0.46	[-0.73, 1.10]	.43	12.20***
	BFIC	-0.29	0.26	[-0.81, 0.23]			-0.19	0.37	[-0.93, 0.55]		
3	TEST x BFIC	-0.78**	0.25	[-1.28, -0.27]	.52	14.91***	0.49	0.39	[-0.28, 1.26]	.43	10.75***

differential associations for subfactors of externalizing behavior. Otherwise, the same IVs were entered in the same steps as described previously and simple slope analyses were conducted to probe significant interaction effects. Conscientiousness significantly moderated the testosterone-Rule-Breaking Behavior relationship (β = -.23, $t(98)$ = -3.06, p = .003). These results are displayed in Table 2. Simple slope analyses indicated that testosterone negatively predicted Rule-Breaking Behavior scores at high (b = -0.88, $t(98)$ = -2.18, p = .032) but not at low (b = 0.67, $t(98)$ = 1.68, p = .097) levels of Conscientiousness, indicating a resiliency effect (see Figure 2). This moderation effect was not found for the prediction of Aggressive Behavior, and Agreeableness did not significantly moderate either Rule-breaking or Aggression associations with testosterone.

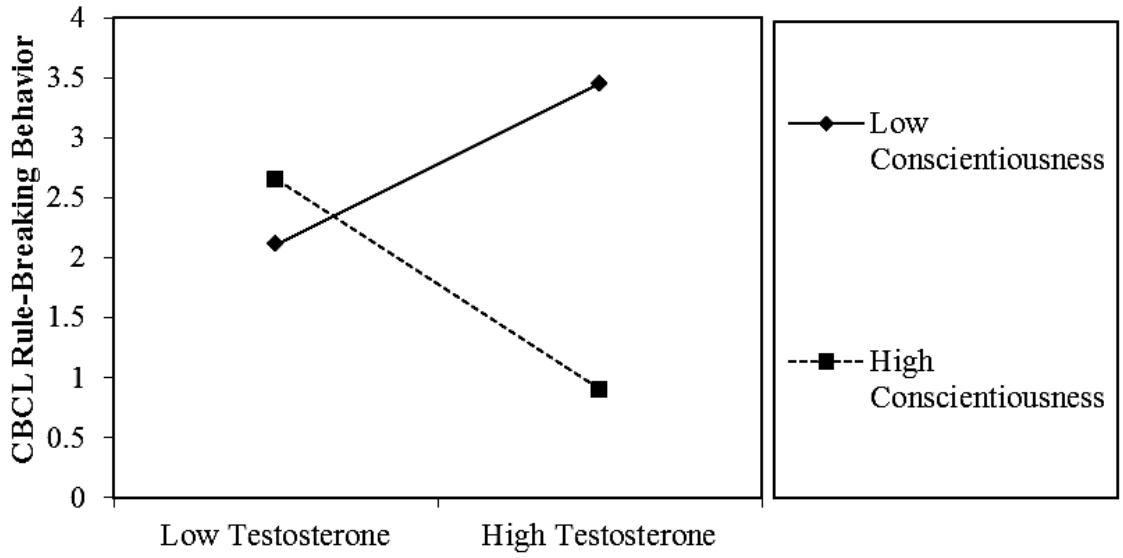

Figure 2. Interaction between testosterone and BFI Conscientiousness in predicting CBCL Rule-Breaking Behavior, controlling for CBCL Aggressive Behavior. BFI = Big Five Inventory; CBCL = Child Behavior Checklist.

Age analyses. Finally, to address the question of differential associations across age, I tested 3-way interactions for linear and quadratic effects of age. These analyses did not find significant interaction effects for age. I further examined whether age differences could be detected via Johnson-Neyman *regions of significance* analyses (Bauer & Curran, 2005; Hayes & Matthes, 2009; Johnson & Neyman, 1936; Kochanska, Kim, Barry, & Philibert, 2011; Preacher, Curran, & Bauer, 2006). According to Hayes & Matthes (2009), this method mathematically derives the points along the moderator variable (age, in this case) where the predictor term (BFI × testosterone interaction term) transitions between statistically significant and nonsignificant, if such a point exists in the data. These points give a range of values along the continuum of the moderator where the predictor term has a statistically significant effect. I used Hayes' MODPROBE syntax (2013) to conduct these analyses, in order to determine whether there were points along the age continuum where the effect of the interaction term between personality and testosterone transitioned from non-significant to significant in predicting Externalizing Behavior scores. The results suggest that there was a region of significance along the age continuum for the interaction term between testosterone and Agreeableness—the lower bound of the region of significance was 15.89 years and the upper bound was 17.27 years. That is, for any single age between the lower and upper bounds of the region of significance, the effect of the interaction term on predicting Externalizing Behavior scores was significant. There was no age-based region of significance for the interaction term between testosterone and Conscientiousness in predicting Externalizing Behavior scores.

Discussion

The current investigation provides novel evidence that self-regulatory personality traits (i.e., agreeableness and conscientiousness) moderate the relationship between testosterone and adolescent externalizing behavior. Previous research has indicated that there is a weak positive correlation between testosterone and externalizing behaviors, but overall findings have been mixed (Book et al., 2001). Findings from this study suggest that the inclusion of self-regulatory personality may allow a more nuanced examination of testosterone-externalizing behavior associations. Specifically, in the context of self-regulatory deficits, testosterone acts as a risk for externalizing behavior outcomes, as initially hypothesized.

Not surprisingly, there was no evidence for main effects of testosterone on the prediction of externalizing behavior. Thus, when examining testosterone-externalizing associations without attention to self-regulatory personality variables, these differential effects are masked. Results robustly supported the primary hypothesis that self-regulatory personality traits would moderate the association between testosterone and externalizing behaviors in adolescence. Specifically, both BFI Agreeableness and BFI Conscientiousness significantly moderated testosterone's prediction of the unique variance in broadband CBCL Externalizing Problems scores (controlling for shared variance with CBCL Internalizing Problems). These findings are largely consistent with evidence that high testosterone acts as a risk factor in the context of high-risk interpersonal relationships (Rowe et al., 2004; Ryan et al., 2013; Vermeersch et al., 2008). The present study extends these findings to intrapersonal self-regulatory deficits.

Regarding the resiliency effect of self-regulatory personality, our results demonstrate that testosterone interacted with Conscientiousness to predict unique variance in rule-breaking behaviors. No similar pattern emerged when predicting unique variance in aggression. These results provide the first extension of evidence that testosterone can buffer against externalizing behavior outcomes in more adaptive interpersonal contexts (Booth et al., 2003; Rowe et al., 2004) by extending this finding to intrapersonal self-regulatory strengths. These results also demonstrate differential associations for behavioral subfactors of externalizing behavior, in line with the second study aim. These results are consistent with the study by Vermeersch and colleagues (2008), which found that testosterone levels were only a significant predictor of non-aggressive risk-taking behavior. They found no similar pattern of results for the prediction of aggressive risk-taking behavior. In addition, the personality trait conscientiousness has been specifically linked with rule-breaking behaviors more strongly than with aggression in previous studies (Burt, 2012).

When examining the potential effects of age in regard to the third study aim, no evidence was found for linear or quadratic effects via three-way interactions. Additional analyses aimed to probe potential regions of significance for age, however, suggested that the moderating effect of Agreeableness was significant for adolescents between ages 15.89 and 17.27 in the present study. These findings can be interpreted in the context of increased prevalence rates of testosterone and externalizing problems across adolescence, an increase which may offer maximal power for detecting such associations. In addition, older adolescents experience greater autonomy than to younger adolescents (Steinberg & Silverberg, 1986), which may strengthen associations between an individual's personality

and behavioral outcomes in mid-late adolescence. Unlike Agreeableness, no regions of significance were detected for Conscientiousness moderation.

Implications

A particularly provocative aspect of the current findings is the parallel pattern of effects we find for self-regulatory personality moderators when compared to previous findings regarding interpersonal relationship moderators such as peer group influences (Rowe et al., 2004; Ryan et al., 2013; Vermeersch et al., 2008). One explanation for these similar findings is that personality and peer group association are two independent influences that interact with high testosterone to impact behavioral outcomes. An alternative explanation is that the influence of peer group association is largely reflective of self-regulatory personality traits. That is, an adolescent's personality trait profile may largely account for their choice in peer group. This latter hypothesis is supported by previous research which suggests that personality may influence peer group selection. In particular, hyperactivity and fearlessness, which can be understood as deficits in self-regulation, predicted involvement with deviant peer groups at a younger age and future antisocial behavior (Lacourse et al., 2006). Self-control has also been found to be a significant longitudinal predictor of associations with deviant peers, such that youths with low self-control select into delinquent peer groups (Chapple, 2005). This evidence suggests that, among those individuals who have intrapersonal self-regulatory deficits, there may be a propensity for deviant peer group association and a higher risk for antisocial behavior. It is important to note, however, that other variables have been found to influence deviant peer group association (such as community disadvantage, parenting quality, and collective socialization; Brody et al., 2001), and that the mechanisms which

underlie deviant peer group selection are not entirely clear (Yanovitzky, 2005). Because of this, future studies incorporation both self-regulatory personality traits and peer-group moderators, as well as research designs better able to disentangle causal effects, will be critical in order to test these competing hypotheses.

As mentioned, Conscientiousness significantly moderated the association between testosterone and unique variance in rule-breaking behaviors, whereas neither Conscientiousness nor Agreeableness moderated the association between testosterone and unique variance in aggression. Specifically, those adolescents with high testosterone displayed higher levels of Rule-Breaking Behavior, but only when Conscientiousness was low. For those adolescents with high Conscientiousness, high testosterone served as a resiliency factor, such that those adolescents with high testosterone and high Conscientiousness displayed lower levels of Rule-Breaking Behavior. It is worth noting that aggression has been found to significantly overlap with general externalizing in factor-analytic studies (Tackett et al., 2003), so that correlates of aggression may be largely identical with those of broadband externalizing psychopathology, which may explain why the prediction of the unique variance in aggression was not significant. These findings are consistent with previous research indicating more associations between testosterone and delinquent behavior than for testosterone and aggression (Booth & Osgood, 1993; Maras et al., 2003; van Bokhoven et al., 2006). These results further emphasize the need to examine externalizing psychopathology at both broad and narrow levels of analysis in empirical research (Burt, 2012; Lahey et al., 1999; Loeber, 1982; Moffitt, 1993).

Limitations and Future Directions

The sample used in the present study included a wide age range of adolescents, which allowed for the preliminary examination of possible age effects; however this age range in combination with the sample size may have limited the ability to detect significant linear or quadratic moderation of these effects. Due to concerns about power, I conducted split-sample analyses by age to further explore the possibility of age effects. The results of the split sample analyses indicated that there are age-related differences, and that follow-up Johnson-Neyman regions of significance testing would be informative. These follow-up analyses did indicate that these relationships may show important changes across adolescent development, as previously discussed. Thus, future research with larger sample sizes or longitudinal data on participants across phases of adolescent development should help to clarify remaining developmental questions about how moderators influence testosterone-externalizing behavior associations.

Another exciting direction for future research is the exploration of inter-individual differences versus intra-individual change in testosterone (Granger, Shirtcliff, Booth, Kivlighan, & Schwartz, 2004; Kivlighan, Granger, & Booth, 2005). Single measurements of testosterone are widely used in behavior research, and supported by large correlations among single-sample testosterone measurements across 7-8 weeks (Dabbs, 1990). Nonetheless, state levels of testosterone do show fluctuations in response to environmental variables such as social threat and challenge paradigms (Maner, Miller, Schmidt, & Eckel, 2008), which means that single-sample measurements may be vulnerable to similar fluctuations. Thus, future studies collecting multiple hormone samples from the same individuals will be better positioned to determine whether state

versus trait testosterone levels are differentially associated with externalizing problems in the context of self-regulatory personality.

Conclusion

Taken together, these results demonstrate that adolescent personality is an important moderating variable in the relationship between testosterone and externalizing behaviors. Specifically, high levels of testosterone predicted high levels of externalizing problems, but only for youth with self-regulatory deficits (i.e., low Agreeableness or low Conscientiousness). Furthermore, high levels of testosterone predicted low levels of rule-breaking behavior in the context of self-regulatory strength (i.e., high Conscientiousness). Thus, high testosterone appears to serve as both risk and resiliency for different types of externalizing behaviors, depending on the adolescent's self-regulatory trait profile. Additionally, these results provide preliminary evidence that there is change in the relationship between testosterone and externalizing behavior across adolescence, but more research is needed to examine exactly how developmental processes impact this relationship. The present study also emphasizes the need to differentiate between subfactors of externalizing behavior (aggression and rule-breaking) since they are differentially linked to self-regulatory personality. Overall, this work highlights the relevance of adolescent self-regulatory personality when examining the link between testosterone and externalizing behavior outcomes.

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